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RESEARCH ARTICLE

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Effects of photoperiod and melatonin on nitrogen partitioning and production performance of Inner Mongolia White Cashmere Goats

Abstract This study investigated the effect of photoperiod and melatonin (MT) on nitrogen partitioning in Inner Mongolia White Cashmere goats in telogen in order to regulate nitrogen partitioning between the body and the fur, and promote cashmere production. Thirty-six castrated mature goats, with live weights ranging from 23 to 25 kg, were randomly allocated into three groups then exposed to different photoperiods (long daily photoperiod, LDPP; short daily photoperiod, SDPP; natural daily photoperiod, NDPP). In each group, half of the goats were implanted with MT. Total nitrogen sediment (ΔN) was tested with a general digestive and metabolism method. Body nitrogen sediment (N_B) was measured by isotope dilution technique of tritiated water at the beginning and at the end of the experiment ($N_B = BN_{\text{end}} - BN_{\text{beg}}$) and fur nitrogen deposited (N_F) was calculated using the formula $N_F = \Delta N - N_B$. Results showed that: (1) there was a significant difference in N_B and N_F partitioning in different treatments of photoperiod and MT. The N_F partitioning was increased with the shortening of photoperiod and it was higher in the implanted groups than in the non-implanted groups. The minimum and maximum percentages in LDPP and SDPP + MT were $(23.6 \pm 0.46)\%$ and $(36.1 \pm 0.79)\%$ respectively. There was a strong interaction between SDPP and implantation of MT; while *BN* partitioning showed the reverse for photoperiod and implantation of MT; (2) there is an additional cashmere production of (338.83 ± 72) g in SDPP and implanted groups with an average increase of 73.86%. The traits of the newly grown cashmere were all in the range of the textile standard; (3) hormones related to nitrogen partitioning and body composition varied with different treatments: the levels of MT and insulin (INS) increased with the shortening of photoperiod and were higher in the implanted groups than in the non-implanted groups, and there was a strong interaction between SDPP and MT implantation; prolactin, insulin like growth factor I and leptin showed the opposite results to MT and INS. This study provides evidence that MT and photoperiod can be used to regulate nitrogen partitioning, modulate cashmere goat body composition and improve cashmere production in practice. The technique can be extended to Inner Mongolia and other cashmere goat raising areas in China.

Keywords photoperiod, melatonin, cashmere goats, nitrogen partition, cashmere

1 Introduction

Cashmere is valued for its softness, lightness and warmth, but its production is very limited on account of the special season and environment. For many years, a lot of techniques and methods have been explored to improve its production. Until now, photoperiod alteration and melatonin (MT) implantation have been the best methods used.

Melatonin (5-methoxy-N-acetyltryptamine, MEL, MLT and MT) is a hormone manufactured by serotonin and secreted by the pineal gland in the brain. Since its identification in 1959 (Lerner, 1959), studies have shown that MT plays a crucial role in ordering the complex hormone secretion patterns that regulate the body's circadian rhythm as well as its metabolism, reproduction, appetite, balance, muscular coordination and immunity. It is regulated by photoperiod daily and seasonally with the rhythmic alteration of light. Darkness stimulates the secretion of MT while light depresses its release. Furthermore, blood MT concentration increases when sunlight shortens after summer solstice but decreases after winter solstice when sunlight lengthens. Studies show that the pelage development of many fur-bearing animals is related to the changes in photoperiod and is actually regulated by MT (Allain and Rougeot, 1980; Rose et al., 1984; Smith

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et al., 1987). It has been reported that cashmere formation could be induced by implanting MT or shortening photoperiod, resulting in an additive cashmere production accompanied with variations in hormones such as prolactin (PRL), GH, insulin like growth factor I (IGF-I) and thyroxine (Betteridge et al., 1987; Moore et al., 1989; Welch et al., 1990). Although most of the studies have shown that cashmere production has improved, there is no report on nitrogen partitioning, especially in Inner Mongolia cashmere goats in China yet. This paper investigates the effects of photoperiod and MT on Inner Mongolia cashmere goats.

2 Materials and methods

2.1 Experiment time and place

The experiment was conducted in Huhhot, Inner Mongolia from February 20 to July 30, 2003, when cashmere goat was in telogen, a period when cashmere growth has ceased.

2.2 Animals and experimental design

Thirty-six selected castrated Inner Mongolia cashmere goats aged 2.3–2.5 years, with body weights from 23 to 25kg, were randomly assigned into three teams, then each team was subdivided into two equal groups. One group in each team was implanted MT on both sides of the neck with the recommended MT dose of 1.86 mg/kg of the bodyweight (Welch, 1990). The three teams were exposed to long daily photoperiod (LDPP, 16 hL:8 hD), natural daily photoperiod (NDPP, 11.3–16 hL) and short daily photoperiod (SDPP, 8 hL:16 hD) in three adjacent rooms (Table 1). The light was provided by cool white fluorescent tubes automatically controlled by a switch. Light intensity was kept within 200–250 lx, similar to natural sunlight. The goats were housed individually in pens of 1.5 m × 2.0 m. Ventilators were used to ventilate the rooms. The ambient temperature was kept within 10–15°C by a warm water equipment that was monitored by thermometers, and the ambient humidity was maintained at 60%–70% as measured by hygrometers.

Table 1 Experimental design and treatments

MT	Photoperiod		
	LDPP, 16 L[a]:8 D[b]	NDPP, 11.3–16 L	SDPP, 8 L:16 D
Implanted	6	6	6
Non-implanted	6	6	6

Note: [a]denotes light; [b]denotes darkness.

2.3 Feeding and management system

The diet of goats consisted of a mixture of roughage and concentrate at ratios of 30:70 and 40:60. The nutrition level of the goat basal diet was referenced from the NRC (1981). The goats were provided with feed containing 1.2 times of metabolism energy and 11.04% of crude protein. Feed composition is listed in Table 2. The goats were fed twice a day at 8:00 am and 16:00 pm. During the experimental period, the goats had free access to water. The diet and remaining feed of each goat was weighed everyday in order to determine its nitrogen intake.

Table 2 Basal diet composition and nutrient level

Ingredient	Percentage	Chemical components	Nutrient level[b]
Hay	70.0	ME/MJ·kg^{-1}	8.65
Corn	18.2	DM/%	90.06
Wheat bran	6.6	CP/%	11.04
Soybean meal	3.0	S/%	0.23
Urea	0.36	Ca/%	0.38
Limestone	0.13	P/%	0.25
Dicalcium phosphate	0.28	N/S	7.68
Salt	1.00	Ca/P	1.52
Premix[a]	0.10	Na/K	1.60
Sodium sulfate	0.33		

Note: [a]Mineral and vitamin premix per kilogram: $FeSO_4 \cdot 7H_2O$ 170 g, $CuSO_4 \cdot 5H_2O$ 70 g, $MnSO_4 \cdot 5H_2O$ 290 g, $ZnSO_4 \cdot 7H_2O$ 240 g, $CoCl_2 \cdot 6H_2O$ 510 mg, KI 220 mg, Na_2SeO_3 130 mg, VA 1 620 000 IU, VD_3 324 000 IU, VE 540 IU, VK_3 150 mg, VB_1 60 mg, VB_2 450, VB_{12} 0.9 mg, VB_5 1 050 mg, calcium pantothenic acid 750 mg, folacin 15 mg; [b]ME was a calculated value, the others were tested.

2.4 Experiment duration

A pre-experiment was conducted 15 days prior to the actual experiment, which was commenced on February 20. Nitrogen metabolism period was calculated for 90 days and observation of cashmere development lasted for 160 days until July 30.

2.5 Detection of nitrogen partitioning

As for the castrated cashmere goats, diet nitrogen sediment (ΔN) consisted of body nitrogen (N_B) and fleece nitrogen (N_F), which was calculated using a digestive and metabolism formula ($\Delta N = N_{\text{intake}} - N_{\text{feces}} - N_{\text{urine}}$). The feces and urine were collected for 20 days and the nitrogen measurement period was 90 days. Body nitrogen sediment (N_B) was measured from the body protein content that was determined by a proven formula for live goats (Panaretto and Till, 1963) using isotope (tritiated water) dilution techniques. The formula is as follows:

$N_B = BN_{\text{end}} – BN_{\text{beg}}$ (N_{end} stands for nitrogen content at the end of the experiment, BN_{beg} represents nitrogen content at the beginning of the experiment).

BN_{end} and BN_{beg} can be calculated by the formula: $BN_{\text{beg}} = CP_{\text{beg}} \times 16\%$, $BN_{\text{end}} = CP_{\text{end}} \times 16\%$ (CP represents body crude protein).

CP (kg) $= 0.255X – 0.35$, $r = 0.969$ (X: ^{3}H space, kg).

Fur nitrogen partition (N_F) was calculated by the formula: $N_F = \Delta N – N_B$.

2.6 Fleece sampling and cashmere detection

Whole fleece samples of 2 cm × 2 cm from behind the shoulder blade of the goats near the midside of the flank that were dyed at the beginning of the experiment were cut down to the skin level monthly during the experiment period. Each succeeding sample area was close to the previous one. The samples were wrapped in paper, sealed in plastic bags and marked correspondingly. At the end of the experiment, a 5 cm × 5 cm fleece was collected to measure the cashmere and the hair ratio of the fleece. After the last sample was obtained, all the goats were exposed to LDPP (16 h) for 1–2 weeks, with the exact time depending on the cashmere shedding condition. When the cashmere began to moult, it was plucked, collected, cleaned and weighed individually. Data on length, diameter and break-strength were taken from the samples.

2.7 Blood sampling and hormone detection

Thirty days after the experiment began, 5 mL of jugular vein blood was collected from each goat every 2 h throughout the day using a clean injector through jugular vein catheters previously fixed on the neck of the goat. The blood was centrifuged at 2 000 g for 15 min, then immediately transferred to a clean container and stored in a −20°C refrigerator for testing of main hormones related to nitrogen partitioning. The plasma hormones tested included MT, PRL, INS, IGF-I and leptin (LEP). The MT and PRL levels were tested by ELISA. The INS, IGF-I and LEP were tested by radioimmunoassay (RIA).

2.8 Statistical analysis

The experiment had six treatments and data obtained were analyzed using the variance procedure of SAS (Statistical Analysis System Institute, 1996). The effects of MT and photoperiod on nitrogen partitioning, hormones and cashmere traits were analyzed using a randomized block ANOVA, and the treatment means were compared using Duncan's multiple range test.

3 Results and discussion

3.1 Effects of photoperiod and MT on nitrogen sediment and partitioning in goats

Photoperiod and MT have a significant effect on nitrogen sediment and partitioning in cashmere goats in telogen (Table 3). The total nitrogen sediment of goats in the three types of photoperiod increased with the shortening of daylength, which was (107.8 ± 8.9) g in LDPP, (112.0 ± 40) g in NDPP and (121.1 ± 12) g in SDPP. The nitrogen sediment percentage of intake of dietary nitrogen was (12.2 ± 1.50)%, (12.2 ± 4.09)% and (12.7 ± 1.17)% respectively, showing an increasing tendency. In the same daily photoperiod groups, the implanted groups had higher values than the non-implanted groups: nitrogen sediment was (16.1 ± 0.54)% for LDPP + MT, (15.8 ± 1.65)% for NDPP + MT and (17.2 ± 4.83)% for SDPP + MT. Long daily photoperiod and NDPP had similar values because they had nearly the same photoperiod length in spring and summer, but they were both lower than the SDPP. Further analysis indicated that there was a significant interaction between photoperiod and MT ($P < 0.01$).

Photoperiod and MT not only influenced nitrogen sediment but also nitrogen partition (Table 3). The result for body nitrogen partition (N_B) was the reverse of fleece nitrogen (N_F); with the shortening of photoperiod, body nitrogen partition decreased but fleece nitrogen partition increased. In the three photoperiods, body nitrogen percentage was (76.4 ± 0.46)% (LDPP), (75.7 ± 0.62)% (NDPP) and (66.3 ± 0.64)% (SDPP). The nitrogen partition decreased with the shortening of photoperiod. In the same photoperiod, the body nitrogen partition in the group of implanted goats was lower than that of the non-implanted goats: (66.3 ± 0.42)% for LDPP + MT, (65.0 ± 0.67)% for NDPP + MT and (63.9 ± 0.79)% for SDPP + MT respectively. The LDPP + MT and NDPP + MT treatments had similar values because their photoperiods were not very discrepant, but they were both different from SDPP + MT. Further analysis showed that there was a significant interaction between photoperiod and MT ($P < 0.01$).

On the other hand, fleece nitrogen percentage increased with the shortening of photoperiod. Fleece nitrogen percentage was (23.6 ± 0.46)%, (24.3 ± 0.62)% and (33.7 ± 0.64)%

Table 3 Dietary nitrogen sediment efficiency and partitioning ratio on cashmere goats in different treatments

Treatment	Nitrogen intake (IN)/g	Total nitrogen sediment (ΔN)/g	ΔN /IN /%	Body nitrogen partition (N_B)/g	N_B/ΔN /%	Fleece nitrogen partition (N_F)/g	N_F /ΔN /%
LDPP	891.7 ± 31^a	107.8 ± 8.9^a	12.2 ± 1.50^a	82.2 ± 6.3^a	76.4 ± 0.46^a	25.6 ± 2.60^a	23.6 ± 0.46^b
LDPP + MT	913.2 ± 33^a	146.8 ± 1.1^a	16.1 ± 0.54^a	97.4 ± 1.4^a	66.3 ± 0.42^b	49.5 ± 0.26^a	33.7 ± 0.42^a
NDPP	896.8 ± 39^a	112.0 ± 40^a	12.2 ± 4.09^a	84.4 ± 29.6^a	75.7 ± 0.62^a	27.6 ± 10.3^a	24.3 ± 0.62^b
NDPP + MT	938.5 ± 14^a	149.0 ± 16^a	15.8 ± 1.65^a	96.7 ± 9.9^a	65.0 ± 0.67^b	52.4 ± 6.58^a	35.0 ± 0.67^a
SDPP	949.1 ± 12^a	121.1 ± 12^a	12.7 ± 1.17^a	80.4 ± 8.8^a	66.3 ± 0.64^b	40.6 ± 3.81^a	33.7 ± 0.64^a
SDPP + MT	892.5 ± 17^a	151.6 ± 40^a	17.2 ± 4.83^a	96.1 ± 24.3^a	63.9 ± 0.79^b	55.5 ± 15.7^a	36.1 ± 0.79^a

Note: The nitrogen partitioning were calculated within 90 days; Means in the same column with different superscript letters differ significantly, and same letter represents non-significance ($P < 0.05$).

for LDPP, NDPP and SDPP respectively. The LDPP and NDPP groups had similar values because they experienced similar photoperiods, but they were significantly lower than the SDPP group. In the same photoperiod, implanted groups had more fleece nitrogen sediment than the non-implanted groups. Their nitrogen percentages were (33.7 ± 0.42)%, (35.0 ± 0.67)% and (36.1 ± 0.79)% for LDPP + MT, NDPP + MT and SDPP + MT respectively. It was enhanced with the shortening of photoperiod, resulting in a significant interaction between photoperiod and MT ($P < 0.01$). The proportion and relationship of body nitrogen and cashmere nitrogen are illustrated in Fig. 1.

The above analysis shows that photoperiod and MT have a significant effect on nitrogen partitioning in cashmere goats. Long daily photoperiod can promote nitrogen distribution to body tissues and muscles, thus improving body nitrogen percentage; SDPP or implant MT may accelerate cashmere growth, thereby enhancing nitrogen distribution to the fleece.

3.2 Effects of photoperiod and MT on cashmere production and quality

As a result of more nitrogen distributed to fleece, cashmere grew rapidly. The experiment continued for 160 days from February 20 to July 30. In autumn, when the normal cycle of cashmere initiated, the supplementary cashmere growth was moulted so that the goats could prepare a new dress of fleece to resist the cold in the winter. Compulsory moulting was conducted for 1–2 weeks after the LDPP treatment. When some of the cashmere had begun to loosen, the outer layer fleece of guard hair was cut off with a pair of long scissors and removed to expose the undercoat of cashmere. The length of removed guard hair depended on the height of cashmere, usually about one half of the guard hair. Then the cashmere was plucked off with a claw-like special tool to condition the goat to be fixed up. When a goat had been completely sheared, cashmere was collected, cleaned, weighed and recorded individually. The results of mean cashmere production in different groups are listed in Table 4.

As shown in Table 4, in SDPP, the implanted groups yielded additional cashmere, which was consistent with nitrogen partitioning. Supplementary cashmere production varied from (285.7 ± 35) to (389.0 ± 54) g, with an average of (338.8 ± 72) g. Total cashmere production reached (679.0 ± 46) to (875.3 ± 118) g. There were no significant differences between the groups in cashmere production; however, SDPP was generally higher than LDPP and NDPP groups. This table shows that SDPP and implanted MT can induce cashmere to grow, alter the annual cashmere growth to biannually, with

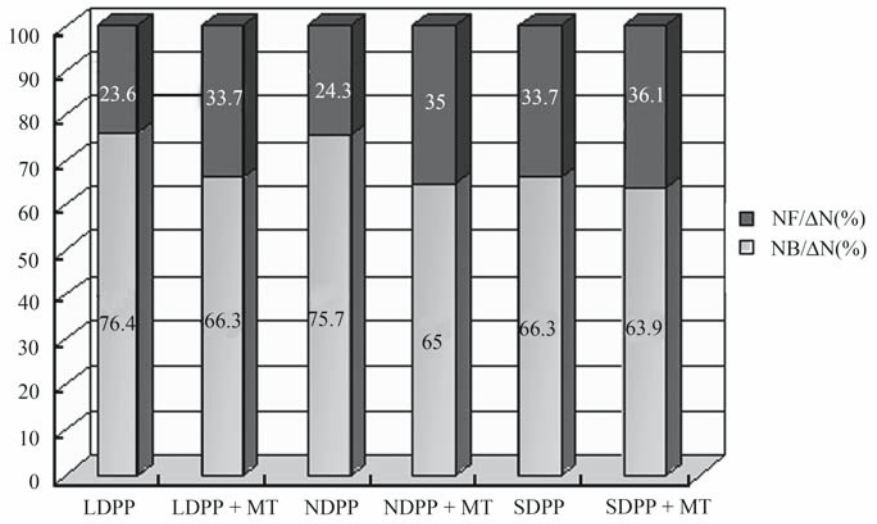

Fig. 1 Percentage of body nitrogen and fleece nitrogen partitioning

Table 4 Cashmere production of the goats in different treatments

Treatment	Cashmere production before experiment/g	Supplement cashmere production in telogen/g	Yearly total cashmere production/g	Increased percentage
LDPP	423.0 ± 60[a]	0	423.0 ± 60[b]	0
LDPP + MT	459.3 ± 58[a]	312.3 ± 42[a]	771.7 ± 100[a]	68.0
NDPP	512.0 ± 36[a]	0	512.0 ± 36[ab]	0
NDPP + MT	496.0 ± 23[a]	368.3 ± 30[a]	864.3 ± 54[a]	74.3
SDPP	486.3 ± 67[a]	389.0 ± 54[a]	875.3 ± 118[a]	80
SDPP + MT	393.3 ± 33[a]	285.7 ± 35[a]	679.0 ± 46[ab]	72.6
Means	461.7 ± 80	338.8 ± 72	687.5 ± 116	73.86

the increase in cashmere production ranging from 68% to 80% or an average increase of 73.86%. There was no valuable cashmere in the LDPP and NDPP. If the cashmere price was 300 Yuan RMB per kilogram, the goats could get an extra profit of 101.65 Yuan RMB on the average.

Aside from cashmere production, an unexpected discovery was that the combined effects of SDPP and implanted MT did not result in the largest yield of cashmere for the SDPP + MT group despite the high percentage of nitrogen distributed to the fleece in the early stage. Further research showed that high levels of blood MT not only promoted more proportion of nitrogen partitioning to cashmere, but also brought side-effects of depression. Moderate treatment of SDPP + MT could accelerate cashmere growth, however, excessive SDPP + MT treatment reduced the movement and appetite of goats, decreasing the total nitrogen intake. Experimental observations revealed that the goats in SDPP + MT group tended to sleep rather than to move because of the high concentration of MT in their blood. In the short term, this behavior could enhance the nitrogen sediment and distribute more percentage of nitrogen to cashmere, but in the long term, it could reduce the total nitrogen intake and the final cashmere production. How much blood MT concentration is moderate remains to be explored. It has been reported that cashmere development largely depends on the transition of LDPP to SDPP, constant SDPP was not the best way for cashmere growth.

As for the quality of induced cashmere, the results are listed in Table 5. The length of induced cashmere reached (5.95 ± 0.26) to (6.32 ± 0.22) cm, the mean length was (6.16 ± 0.24) cm. There was no marked difference between the induced groups, but it was significantly shorter than the length that grew under normal (original) grazing conditions. However, the length exceeded the requirement of the textile standard of 4.0 cm. The diameter of induced cashmere was also smaller than the original ones, and mean diameter was decreased by 0.38 μm from (15.15 ± 0.33) to (14.77 ± 0.32) μm. This reduction was not evident in the induced groups and there was no significant difference between them. This appears to be a good thing for textile because it is difficult to reduce cashmere diameter. Most of the previous reports have shown that induced cashmere becomes thick (Jia, 1994). This may be due to the species of the animals. On the other hand, fineness of cashmere does not result in benefits because it is detrimental to the fiber break-strength, which is unacceptable to the textile industry. In the four groups, induced cashmere break-strength was weaker than the original, but it was still eligible for the fiber classification standard of grade A ($\geqslant 3.5$ cN), except for the NDPP + MT group whose value fell in the grade B range (3.2 cN $\leqslant$ B $\leqslant 3.5$ cN). The results therefore elucidated that the induced cashmere was suitable for the textile industry. Overall, all the evidences show that it is feasible to apply the technique of SDPP and implanting MT to enhancing cashmere production.

3.3 Mechanism of photoperiod and MT action on cashmere

Short daily photoperiod and MT can promote nitrogen distribution to the fleece and improve cashmere production. The physiological mechanism of this action is due to the alteration of hormones in the goat blood. The main hormone concentrations associated with cashmere growth and nitrogen partitioning were studied, and the results are listed in Table 6.

As shown in Table 6, photoperiod and MT exhibit distinct effects on many other hormones. There are five hormones that

Table 5 The length, diameter and break-strength of induced cashmere

Treatment	Length of cashmere/cm		Diameter of cashmere/μm		Break-strength of cashmere/cN	
	Original cashmere	Induced cashmere	Original cashmere	Induced cashmere	Original cashmere	Induced cashmere
LDPP	9.40 ± 0.85^{a}	$\underline{3.98 \pm 0.35}^{c}$	15.37 ± 0.15^{a}	0	4.77 ± 0.29^{bc}	0
LDPP + MT	8.07 ± 1.08^{a}	5.95 ± 0.26^{b}	14.88 ± 0.15^{a}	14.77 ± 0.35^{a}	5.91 ± 0.55^{a}	4.58 ± 0.43^{a}
NDPP	11.04 ± 0.83^{a}	$\underline{3.22 \pm 0.30}^{c}$	14.65 ± 0.50^{a}	0	5.39 ± 0.11^{ab}	0
NDPP + MT	9.41 ± 0.05^{a}	6.32 ± 0.22^{a}	15.40 ± 0.37^{a}	14.83 ± 0.22^{a}	4.82 ± 0.23^{bc}	3.24 ± 0.16^{c}
SDPP	9.46 ± 0.81^{a}	6.17 ± 0.20^{a}	15.46 ± 0.37^{a}	15.03 ± 0.51^{a}	5.33 ± 0.15^{ab}	4.39 ± 0.43^{ab}
SDPP + MT	9.02 ± 1.60^{a}	6.20 ± 0.29^{a}	15.14 ± 0.63^{a}	14.43 ± 0.28^{a}	5.29 ± 0.61^{ab}	3.67 ± 0.28^{bc}
Mean	9.40 ± 0.87	6.16 ± 0.24	15.15 ± 0.33	14.77 ± 0.32	5.25 ± 0.31	3.97 ± 0.33

Note: The underlined values in the LDPP and NDPP treatments were vellus fibre, which has no valuable use in the textile industry.

Table 6 Main related hormones in different treatments

Treatment	MT/pg · mL^{-1}	PRL/ng · mL^{-1}	IGF-I/ng · mL^{-1}	INS/ng · mL^{-1}	LEP/ng · mL^{-1}
LDPP	62.5 ± 8.3^{b}	28.5 ± 5.38^{a}	228.9 ± 7.7^{a}	13.2 ± 0.93^{c}	8.0 ± 0.53^{a}
LDPP + MT	317.6 ± 28.5^{a}	1.2 ± 0.03^{b}	174.1 ± 4.4^{b}	19.6 ± 3.43^{b}	7.2 ± 0.43^{ab}
NDPP	67.7 ± 14.6^{b}	7.4 ± 2.09^{b}	197.2 ± 6.8^{b}	14.5 ± 0.94^{bc}	7.4 ± 0.58^{ab}
NDPP + MT	282.7 ± 20.9^{a}	3.2 ± 1.18^{b}	178.5 ± 6.3^{b}	17.6 ± 0.93^{bc}	6.5 ± 0.41^{ab}
SDPP	87.9 ± 14.1^{b}	6.4 ± 2.31^{b}	185.3 ± 6.7^{b}	15.5 ± 1.31^{bc}	7.3 ± 0.58^{ab}
SDPP + MT	332.5 ± 56.2^{a}	2.5 ± 0.63^{b}	121.9 ± 3.6^{c}	31.2 ± 3.44^{a}	6.2 ± 0.44^{b}

show photosensitivity, and their concentrations can be altered by changing photoperiod and implanting MT. However, the alteration is not consistent. The hormones can be categorized into two kinds. One kind decreases with the shortening of photoperiod, which includes PRL, IGF-I and LEP. The other kind increases with the shortening of photoperiod, which includes MT and INS. Besides photoperiod, MT also exerts some effects on other hormones that can influence their levels (Fig. 2). Each of the hormones has a special function in the body and their interaction can drive nitrogen distribution to different parts of the body. The detailed interaction is depicted in Fig. 3.

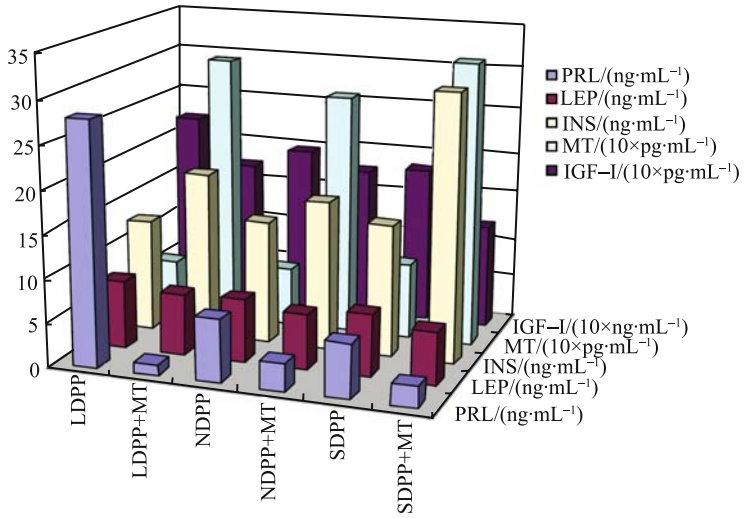

Fig. 2 Concentration of related hormones in different groups

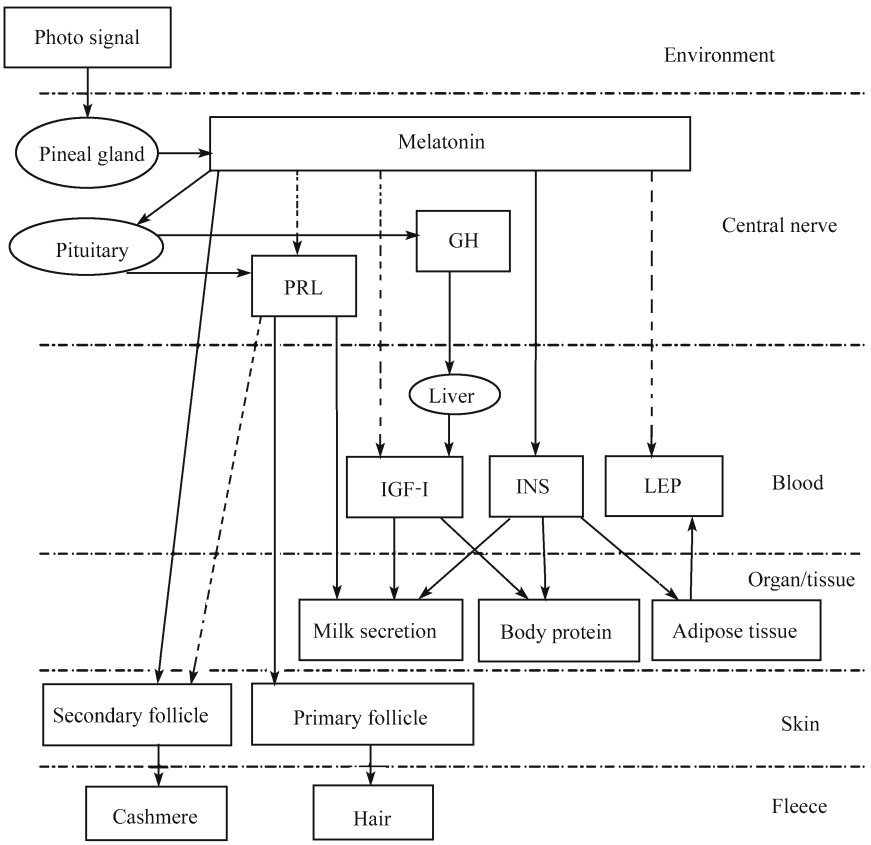

Fig. 3 Regulative mechanism of photoperiod and melatonin on nitrogen partitioning and cashmere development in cashmere goats (⟶ positive feedback, - - -► negative feedback)

The effects of photoperiod and MT complete our work on several levels. First, from outside, the environmental short photoperiod signal stimulates the photosensitive cells in the pineal gland secreting MT through the retina, increasing blood MT concentration, and the MT exerts negative effects on PRL, IGF-I and LEP.

Prolactin exerts its effects on the primary follicle, secondary follicle and mammary gland. In the mammary gland, it regulates milk secretion. On the skin level, it contributes to the formation and development of primary follicles while inhibiting the formation and development of secondary follicles. Melatonin and PRL exhibit a competitive inhibitory relationship on the secondary follicles. In LDPP and NDPP groups, the goat blood MT concentration was low, secondary follicle activation was depressed, and cashmere development was inhibited. In SDPP and implanted groups, blood MT levels rose. This suppressed the effects of PRL, and as a result, the secondary follicles were relieved and began to grow, subsequently promoting cashmere growth, and more nitrogen were partitioned to fleece.

Insulin like growth factor I plays an important role in protein synthesis in the goat body. In LDPP and NDPP groups, the goat blood IGF-I concentration was high, which could accelerate the body protein synthesis, such as in muscles, organs, hair keratin and other body tissues, and body nitrogen partitioning was correspondingly high. In SDPP and implanted groups, raising blood MT could decrease the concentration of IGF-I, weakening the body and milk protein synthesis, if the goat was in lactation.

Photoperiod and MT implantation have similar effects on LEP. However, the alteration was not clear compared with PRL and IGF-I. One of the functions of LEP is associated with the body adipose content and regulation of its metabolism speed. A high level of blood LEP can accelerate body fat decomposition and oxidation, and reduce body adipose content relative to body composition (Wang et al., 2005). In LDPP and NDPP groups, the high level of LEP promoted body fat decomposition and reduced its content, but in SDPP and implanted groups, the high level of MT depressed LEP concentration and inhibited adipose decomposition, subsequently increasing the body fat content.

On the other hand, a high level of MT can boost INS concentration. Insulin can enhance the synthesis of body fat and protein, as well as the secretion of milk fat and protein in the mammary gland. Our previous study showed that there was a higher proportion of fat in SDPP and implanted groups than in LDPP and NDPP groups (Wang et al., 2005).

All the evidence and analyses indicate that a high concentration of MT in SDPP and implanted groups can control a group of hormones that play special roles in nitrogen partitioning and body component metabolism. These functions ultimately result in supplementary cashmere and the alteration of body composition. There are no evidences to present regarding whether or not this alteration could bring side-effects on goats.

3.4 Application of photoperiod and MT

Melatonin at different photoperiods can result in different changes on blood hormones. This has different effects on cashmere goat because MT drives nutrient (nitrogen) partitioning to different parts of the body leading to differences in production. Accordingly, photoperiod can be used bidirectionally to modulate the body component of cashmere goats to produce cashmere or meat depending on human demand. When we want to harvest more cashmere or fatty meat, the technique of SDPP or implanting MT can be used, but when we want to get more lean meat, LDPP can be used to achieve it. Application of photoperiod and MT should be in accordance with reality: changing photoperiod is convenient for the housing goat, and implanting MT is easy for grazing goat.

Actually, the extension of this technique in practice on large cashmere breeding areas needs further research and application. Though the exact benefit from the application cannot be estimated, it will change the traditional grazing management pattern into a combination of grazing and housing feeding system. Obviously, the new system will increase the feeding cost, but the additional financial income will counteract or exceed it. In the long run, it is also beneficial to grassland protection and environmental melioration, and more benefits need to be examined.

4 Conclusions

It can be concluded from this study that cashmere production may be maximized in telogen by changing LDPP to SDPP or directly implanting MT in the body of goat. In addition, cashmere development and body composition alteration could be easily manipulated by altering the photoperiod or implanting MT and regimenting a series of hormones. Cashmere production could be increased by $>70\%$ through biannual yielding, and the quality of induced cashmere also meets the textile standard without evident defects.

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